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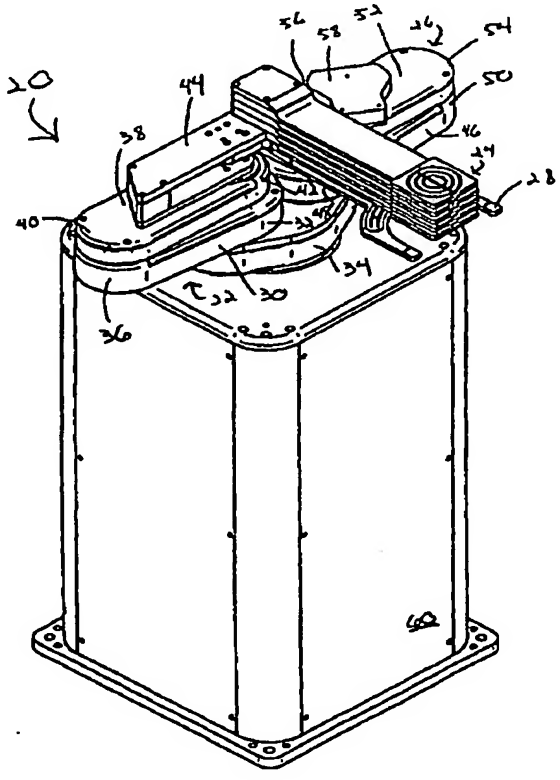
(54) Title: DUAL ARM SUBSTRATE HANDLING ROBOT WITH A BATCH LOADER

(57) Abstract

A substrate handling robot (20) includes an arm drive mechanism (34). A first arm (22) is connected to the arm drive mechanism. A multiple substrate batch loader (24) is connected to the first arm. A second arm (26) is also connected to the arm drive mechanism. A single plane end effector (28) is connected to the second arm. The multiple substrate batch loader produces a vacuum signal indicative of how many substrates are held thereby. A vacuum signal interpreter alters the movement of the first arm in response to the substrate load number. An object sensor (58) is connected to the second arm. The object sensor assesses the number of substrates in a cassette adjacent to the multiple substrate batch loader. A substrate loading sequence controller controls the arms in response to the number of substrates in the cassette to facilitate complete loading of the multiple substrate batch loader.



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DUAL ARM SUBSTRATE HANDLING ROBOT WITH A BATCH LOADER

Brief Description of the Invention

This invention relates generally to automated systems for transporting materials. More particularly, this invention relates to a dual arm substrate handling robot with a batch loader.

Background of the Invention

Robots are used in a variety of industrial processes. For example, robots are used to handle substrates in the electronics industry. The term substrate includes such devices as semiconductor wafers, liquid crystal displays, flat panel displays, disk drives, and the like. Substrates are commonly stored in cassettes. In the case of a semiconductor wafer, a cassette of wafers is delivered to a work area. A robotic arm is used to take a single wafer from the cassette and deliver it to a pre-aligner. Once the wafer is pre-aligned, the robotic arm delivers the wafer to a testing apparatus. When testing is completed, the wafer is returned to the original cassette or a different cassette by the robotic arm. While existing robotic arms are acceptable for individual manipulation of substrates in a cassette, they are relatively inefficient for rapidly dispatching a set of substrates from one cassette to another or performing other types of bulk transfer operations.

Thus, it would be highly desirable to provide an improved technique for robotic-based bulk transfers of substrates. Ideally, the bulk transfer technique would be capable of transferring various numerical combinations of substrates to optimize transfer operations. The bulk transfer technique would preferably have a low cost mechanism for determining the number of substrates being transferred at any given time and would adjust the speed of its motion accordingly. Such a device should use known materials and techniques and otherwise be compatible with existing robotic processes.

Summary of the Invention

The apparatus of the invention includes a substrate handling robot with an arm drive mechanism. A first arm is connected to the arm drive mechanism. A multiple substrate batch loader is connected to the first arm. A second arm is also connected to the arm drive mechanism. A single plane end effector is connected to the second arm. The multiple substrate batch loader senses a vacuum signal indicative of how many substrates are held by the multiple substrate batch loader. A vacuum signal interpreter selectively alters the movement of the first arm in response to the substrate load number. An object sensor is connected to the second arm. The object sensor assesses the number of substrates in a cassette adjacent to the multiple substrate batch loader. A substrate loading sequence controller controls the first arm and the second arm in response to the number of substrates in the cassette, such that the second arm removes substrates from the cassette in such a manner as to facilitate complete loading of the multiple substrate batch loader.

The method of the invention includes the step of removing a first substrate from a storage site with a single paddle. A set of substrates are removed from the storage site with a multiple substrate batch loader. A vacuum signal indicative of how many substrates are held by the multiple substrate batch loader is obtained. The motion of the multiple substrate batch loader is altered when the vacuum signal indicates that the multiple substrate batch loader is not fully loaded. The method may also include the step of assessing the number of substrates in the storage site. Individual substrates may be removed from the storage site to facilitate complete loading of the multiple substrate batch loader.

The invention provides an improved technique for robotic-based bulk transfers of substrates. The bulk transfer technique of the invention allows for the transfer of various numerical combinations of substrates to optimize transfer operations. The vacuum sensor associated with the multiple substrate batch loader facilitates a low cost assessment of the number of substrates being transferred at any given time. Based upon this information, the motion of the robot may be altered. Advantageously, the invention utilizes known materials and techniques and is otherwise compatible with existing processes.

Brief Description of the Drawings

For a better understanding of the invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a perspective view of a dual arm batch loading robot in accordance with an embodiment of the invention.

FIGURE 2 is a side view of the apparatus of Figure 1.

FIGURE 3 is an exploded view of the dual arm structure of the apparatus of Figure 1.

FIGURES 4A and 4B provide cross sectional views of a portion of the apparatus of Figure 1.

FIGURE 5 is an exploded view of a single plane end effector utilized in accordance with the apparatus of Figure 1.

FIGURE 6 is an exploded view of a multiple substrate batch loader utilized in accordance with the apparatus of Figure 1.

FIGURE 7 illustrates the apparatus of Figure 1 being operated in connection with a control device in the form of a general purpose computer.

Like reference numerals refer to corresponding parts throughout the drawings.

Detailed Description of the Invention

Figure 1 is a perspective view of a dual arm batch loading robot 20 in accordance with an embodiment of the invention. The robot 20 includes a first arm 22, which supports a multiple substrate batch loader 24. The robot also includes a second arm 26, which supports a single plane end effector 28.

The first arm 22 includes a base arm 30 with a proximal end 32 connected to an arm drive mechanism 34. The base arm 30 also includes a distal end 36. The first arm also includes a forearm 38. The proximal end 40 of the forearm 38 is connected to the distal end 36 of the base arm 30. The distal end 42 of the forearm 38 supports a batch loader support mechanism 44.

The second arm 26 includes a base arm 46 with a proximal end 48 and a distal end 50. A forearm 52 has a proximal end 54 connected to the distal end 50 of the base arm 46. An object sensor 58 is connected to the distal end 56 of the forearm 52. Figure 1 also illustrates a housing 60, which encloses a motor and other components.

Those skilled in the art will recognize a number of benefits associated with the apparatus of Figure 1. The multiple substrate batch loader 24 allows a set of substrates to be transported, thereby increasing processing efficiency. The single plane end effector 28 allows the robot 20 to perform traditional substrate handling operations. Other advantages and benefits of the invention are highlighted with the following discussion.

Figure 2 is a side view of the robot 20. The figure illustrates the housing 60, the arm drive mechanism 34, the single plane end effector 28, and the multiple substrate batch loader 24.

Figure 3 is an exploded rear view of the first arm 22 and second arm 26. The figure illustrates the first arm 22 and its base arm 30, the distal end 36 of which receives a pivot mechanism 70. The proximal end 40 of the forearm 38 is also attached to the pivot mechanism 70. Similarly, the distal end 50 of the second arm 26 has an aperture 51 to receive a pivot mechanism 72 associated with forearm 52.

Figure 3 also illustrates a portion of the arm drive mechanism 34. The arm drive mechanism 34 includes a dual shaft drive mechanism 74, which is used to provide motive force for the arms 22 and 26. A drive shaft housing 76 encloses the dual shaft drive mechanism 74. The drive shaft housing 76 rests on top of a motor housing frame 78. A motor (not shown) is positioned within the motor housing frame 78. A motor housing exterior 80 encloses the motor housing frame 78.

Figure 4A is a cross sectional view of a portion of the robot 20. In particular, the figure illustrates the first arm 22 and a portion of housing 60 in cross-section. The figure illustrates the dual shaft drive mechanism 74 with a first shaft 82. The shaft 82 is connected to a belt 84, which is linked to a pulley 86. A similar arrangement is used in connection with the second arm 26. The particular internal arm drive mechanism used in connection with the invention is immaterial, since any number of configurations may be used in accordance with the invention. The invention is not directed toward robotic arm movements, but to the use of a multiple substrate batch loader 24, a single plane end effector 28, and the associated utilization of these devices, as further discussed below.

Although the particular internal arm drive mechanism that is used is not critical to the operation of the invention, one particular configuration has been found to be advantageous. Figure 4B illustrates the use of a harmonic drive mechanism (gear

reduction unit) which is instrumental in providing smooth motion and enough torque to move multiple wafers. The gear reduction unit reduces moving parts, provides a strong drive system, avoids the problem of belt wear, and is relatively compact. In addition, it is housed in the arm base for easy accessibility for servicing.

Figure 4B illustrates that the pulley 86 rotates the shaft 87, which drives the input portion of the harmonic drive 88. The output portion of the harmonic drive 88 is attached to a radial link 89, which in turn is attached to the arm base 30 through spacer 91.

Figure 5 is an exploded view of a single plane end effector 28 in accordance with an embodiment of the invention. The device 28 has a connector 90 for attachment to the second arm 26. An intermediate support member 92 is attached to the connector 90. A single plane paddle 96 is attached to the intermediate support member 92. An object sensor 58 is connected to the base of the single plane paddle 96. The object sensor 58 may be an optical sensor, a laser sensor, or the like. The object sensor 58 is used to identify whether substrates are stored at a storage site, such as a cassette. The second arm 26 is manipulated through a variety of positions to allow the object sensor 58 to identify where objects are stored. Figure 5 also illustrates that the paddle 96 includes a vacuum aperture 98. The vacuum aperture is linked to a vacuum pump (not shown). The vacuum pump establishes suction that secures a substrate to the paddle 96.

Figure 6 illustrates a multiple substrate batch loader 24 in accordance with an embodiment of the invention. The device 24 includes a first arm connector 100 for connection with the first arm 22. A stand-off 102 is positioned on the first arm connector 100. An elevated base member 104 is positioned on the stand-off 102. A first paddle 106 is positioned and secured between the first arm connector 100 and the elevated base member 104. The first paddle 106 includes a vacuum aperture 108, which operates in the manner described with respect to the vacuum aperture 98 of paddle 96. Figure 6 illustrates that the multiple substrate batch loader 24 may also include any number of additional paddles 116. Each additional paddle 116 includes a paddle plateau 117, which operates as a stand-off for an adjacent paddle. Each additional paddle 116 also includes a vacuum aperture 108. A paddle cap 118 may be used to secure the vertical arrangement of paddles 116. Each paddle in the multiple

substrate batch loader 24 contains an internal vacuum channel. An O-ring is used to seal the vacuum channel between components.

Figure 7 is a simplified illustration of the dual arm batch loading robot 20. The figure illustrates in simplified form the multiple substrate batch loader 24 and the single plane end effector 28. As previously discussed, these components are attached to an arm drive mechanism 34. The arm drive mechanism 34 preferably includes a vacuum sensor 119. The vacuum sensor is used to measure the vacuum signals associated with the various vacuum apertures of the multiple substrate batch loader 24, as further discussed below. Figure 7 illustrates that the dual arm batch loading robot 20 may operate in connection with a cassette 140, which holds a set of substrates 141.

Figure 7 also illustrates that the dual arm batch loading robot 20 may be controlled by a control circuit in the form of a general purpose computer 120. The computer 120 includes a set of input/output devices 122 to interface with the robot 20. The input/output devices 122 also include such items as a keyboard, mouse, monitor, printer, and the like. Control signals to and from the robot 20 are exchanged through the input/output devices 122. The control signals include vacuum sensor signals from the vacuum sensor 119 and sensed object signals from the object sensor 58. These signals are passed to the central processing unit (CPU) over bus 126. The bus 126 is also connected to a memory (e.g., RAM, disc memory, or the like) 128, allowing the CPU 124 to execute programs stored within the memory 128. The operation of a computer in connection with input/output devices 122, a CPU 124, and a memory 128 is well known in the art. An aspect of the invention is directed toward the particular types of programs executed by the computer 120.

In accordance with the invention, the memory 128 preferably stores a substrate loading sequence controller program 130, a vacuum signal interpreter program 132, and a motion control unit program 134. The motion control unit program is a standard program for generating control signal for the arm drive mechanism 34. As known in the art, the motion control unit 134 relies upon information from the map sensor 121.

The substrate loading sequence controller 130 is executed by the CPU 124 to select an optimal transport sequence to be performed by the robot 20. The substrate loading sequence controller 130 determines which arm to use when dealing with a partially filled cassette. For example, if the object sensor 58 detects three substrates in the bottom slots of a cassette, a missing substrate above those three, and a group of

five substrates above that, the controller 130 can select the single plane end effector 28 to move the first three substrates individually, skip the empty slot, then move the group of five with the multiple substrate batch loader 24. Thus, based upon the information accumulated by the object sensor 58, the controller 130 executes a set of rules to optimize the utilization of the multiple substrate batch loader 24. The execution of these rules typically results in the use of the single plane end effector 28 to move substrates such that groups of substrates are subsequently dispatched with the multiple substrate batch loader 24.

The vacuum signal interpreter 132 as executed by the CPU 124 processes the control signal from the vacuum sensor 119. The vacuum sensor 119 is tied to each of the vacuum apertures of the individual paddles of the batch loader 24. Since the batch loader 24 has all of its blades tied into a single vacuum source, there is only one vacuum sensor which is used to detect the presence of the substrates. If only four out of five wafers are present, a "vacuum leak" on the blade without a wafer is reflected in an altered vacuum signal. The vacuum leak results in reduced suction at the remaining substrates. In response to this condition, the vacuum signal interpreter reduces the speed of the arm 22 to insure safe transport of the substrates. Observe that the object sensor 58 will typically provide information as to how many substrates will be carried at any given time. However, the vacuum signal interpreter 132 operates as a redundant failsafe mechanism, or alternatively, as a substitute mechanism if an object sensor 58 is not available. The vacuum signal interpreter 132 may be implemented as simple circuit that determines whether any paddle is not carrying a substrate. In response to such a condition, the altered movement of the robotic arm can be adjusted. In other words, in this embodiment the vacuum signal is not mapped to a specific number of substrates that are missing in the batch loader. Instead, if only a single substrate is missing the motion of the arm is adjusted.

Those skilled in the art will appreciate that the invention provides an improved technique for robotic-based bulk transfers of substrates. The bulk transfer technique of the invention allows for the transfer of various numerical combinations of substrates to optimize transfer operations. The vacuum sensor associated with the multiple substrate batch loader facilitates a low cost assessment of the number of substrates being transferred at any given time. Based upon this information, the motion of the

robot may be altered. Advantageously, the invention utilizes known materials and techniques and is otherwise compatible with existing robotic processes.

The foregoing description, for purposes of explanation, used specific nomenclature to provide a thorough understanding of the invention. However, it will be apparent to one skilled in the art that the specific details are not required in order to practice the invention. In other instances, well known circuits and devices are shown in block diagram form in order to avoid unnecessary distraction from the underlying invention. Thus, the foregoing descriptions of specific embodiments of the present invention are presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, obviously many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following Claims and their equivalents.

IN THE CLAIMS:

1. A substrate handling robot, comprising:
an arm drive mechanism;
a first arm connected to said arm drive mechanism;
a multiple substrate batch loader connected to said first arm;
a second arm connected to said arm drive mechanism; and
a single plane end effector connected to said second arm.

2. The substrate handling robot of claim 1 wherein said multiple substrate batch loader includes a plurality of vertically stacked substrate handling paddles.

3. The substrate handling robot of claim 2 wherein each substrate handling paddle of said plurality of vertically stacked substrate handling paddles includes a vacuum aperture.

4. The substrate handling robot of claim 3 further comprising a vacuum sensor to receive a vacuum signal from each vacuum aperture of said vertically stacked substrate handling paddles.

5. The substrate handling robot of claim 4 further comprising a vacuum signal interpreter connected to said vacuum sensor to determine a substrate load number indicative of how many substrates are held by said multiple substrate batch loader.

6. The substrate handling robot of claim 5 wherein said vacuum signal interpreter alters the movement of said first arm in response to said substrate load number.

7. The substrate handling robot of claim 1 further comprising an object sensor connected to said second arm.

8. The substrate handling robot of claim 7 wherein said object sensor assesses the number of substrates in a cassette adjacent to said multiple substrate batch loader.

9. The substrate handling robot of claim 8 further comprising a substrate loading sequence controller to control said first arm and said second arm in response to said number of substrates in said cassette, such that said second arm removes substrates from said cassette in such a manner as to facilitate complete loading of said multiple substrate batch loader.

10. A method of removing substrates from a storage site, said method comprising the steps of:

removing a first substrate from a storage site with a single paddle; and

withdrawing a plurality of substrates from said storage site with a multiple substrate batch loader including a plurality of paddles.

11. The method of claim 10 further comprising the step of obtaining a vacuum signal from said multiple substrate batch loader indicative of how many substrates are held by said multiple substrate batch loader.

12. The method of claim 10 further comprising the step of altering the motion of said multiple substrate batch loader when said multiple substrate batch loader is not fully loaded.

13. The method of claim 10 further comprising the step of assessing the number of substrates in said storage site.

14. The method of claim 13 further comprising the step of removing individual substrates from said storage site to facilitate complete loading of said multiple substrate batch loader.

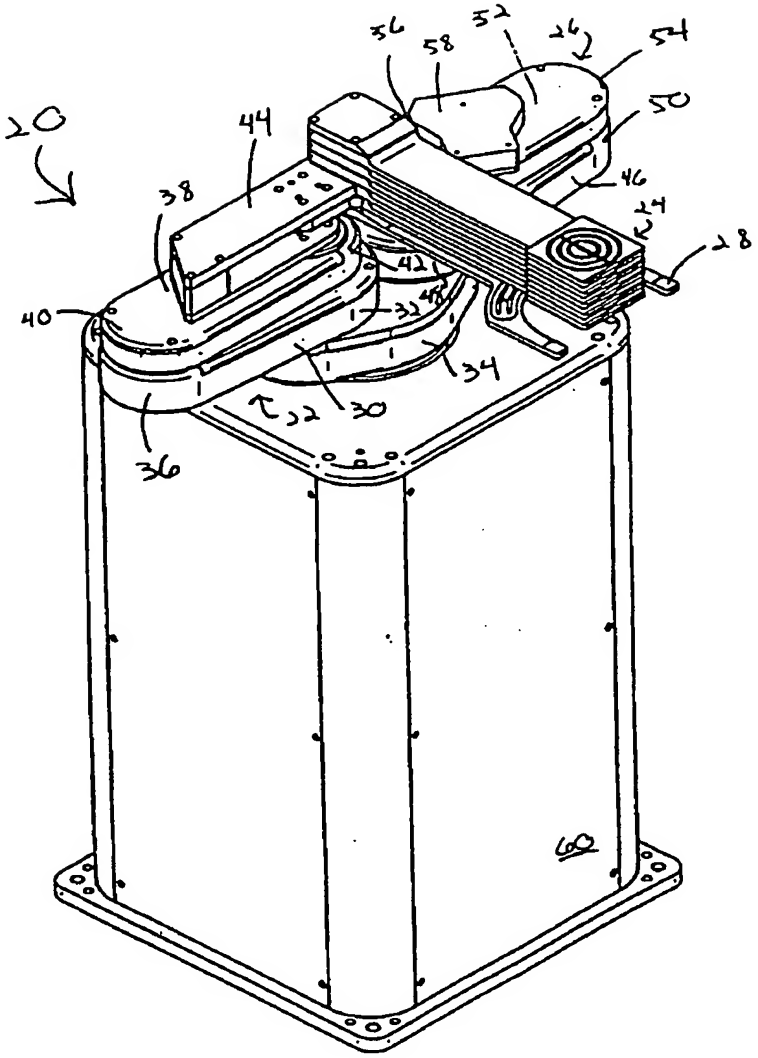

Fig. 1

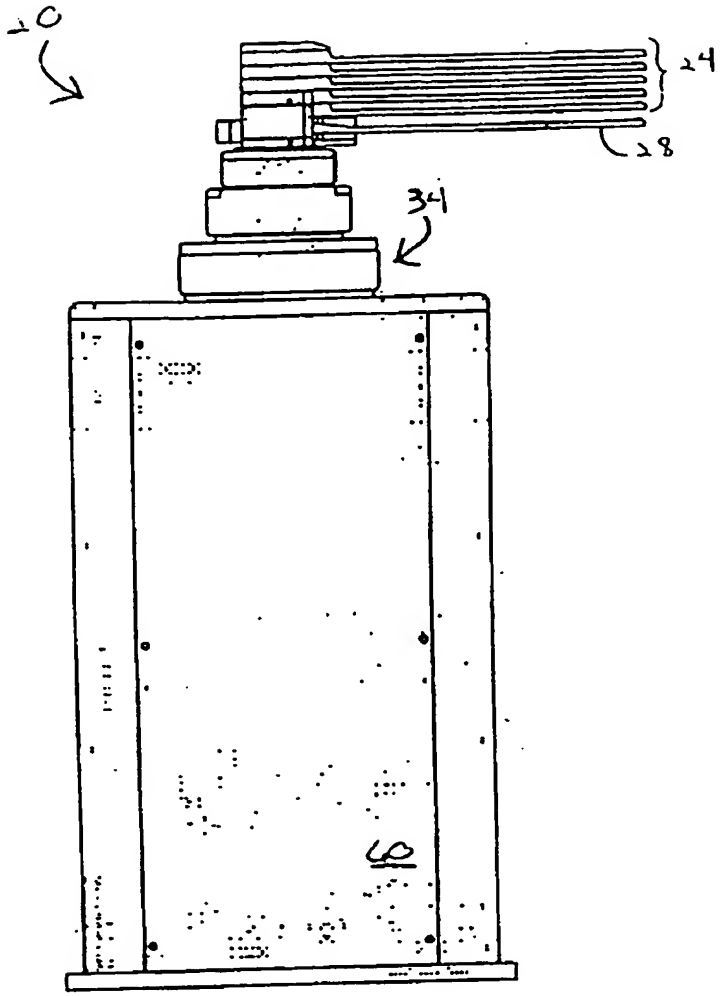

Fig. 2

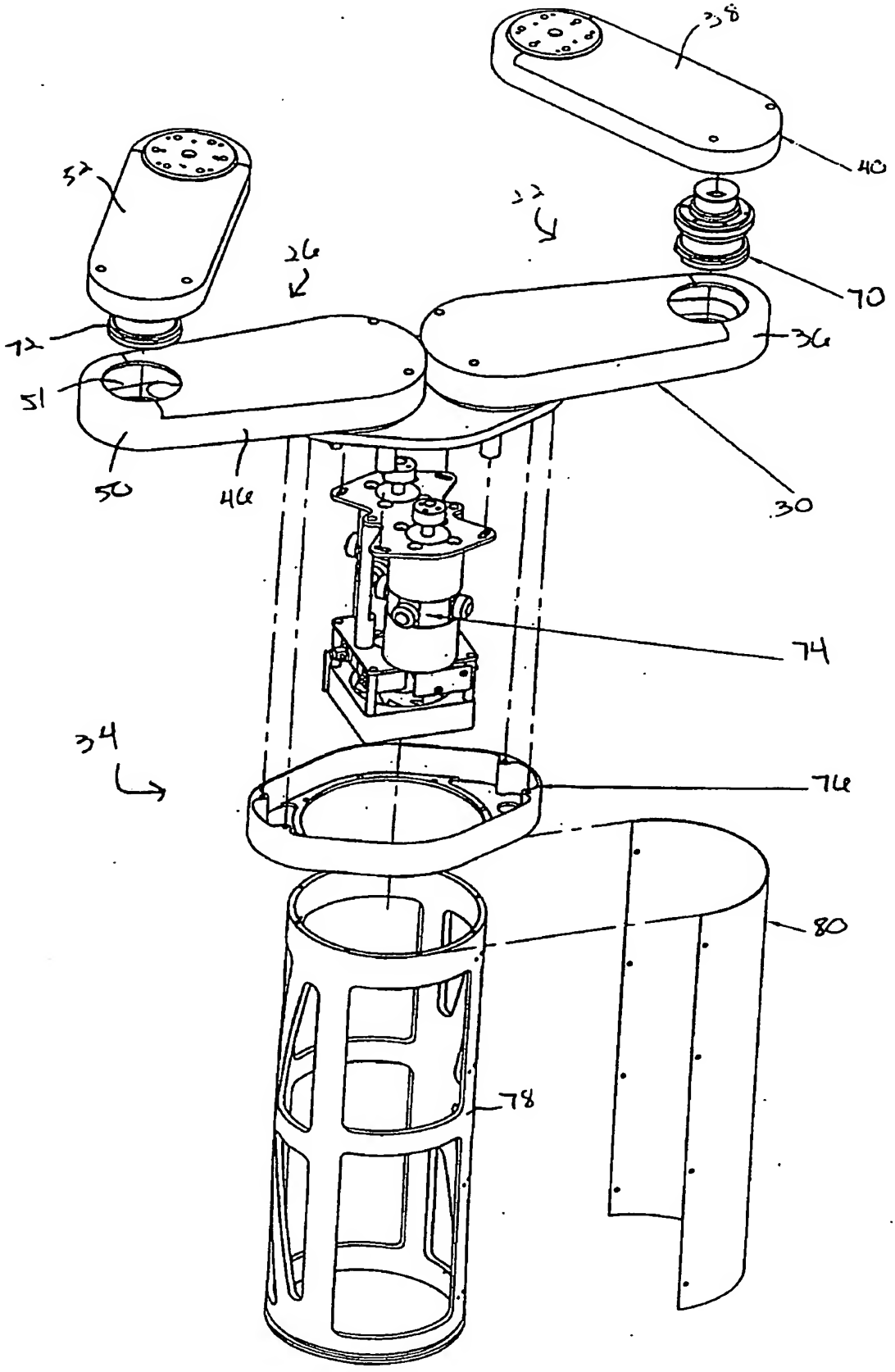

Fig. 3

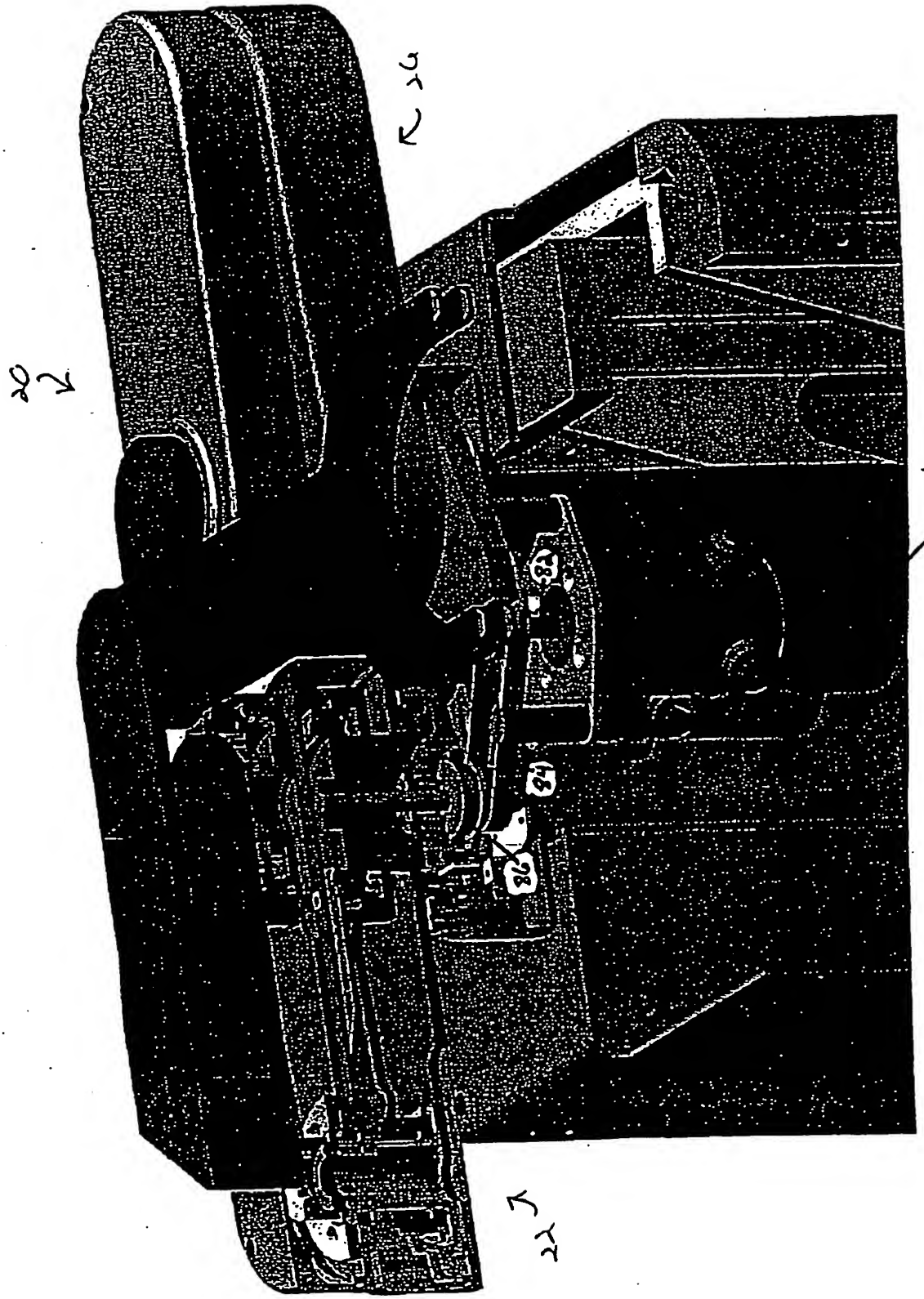

Fig. 4

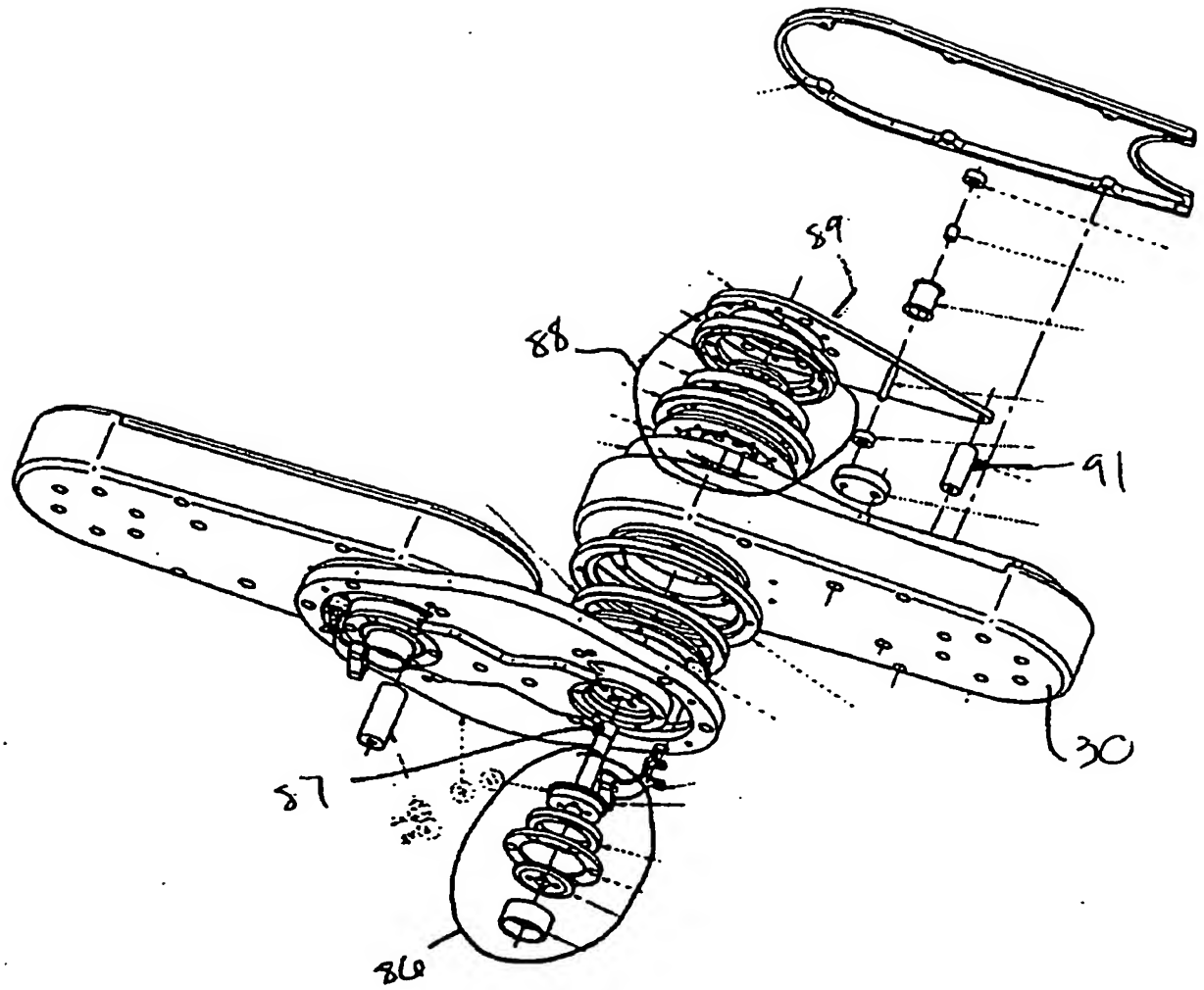

Fig. 4B

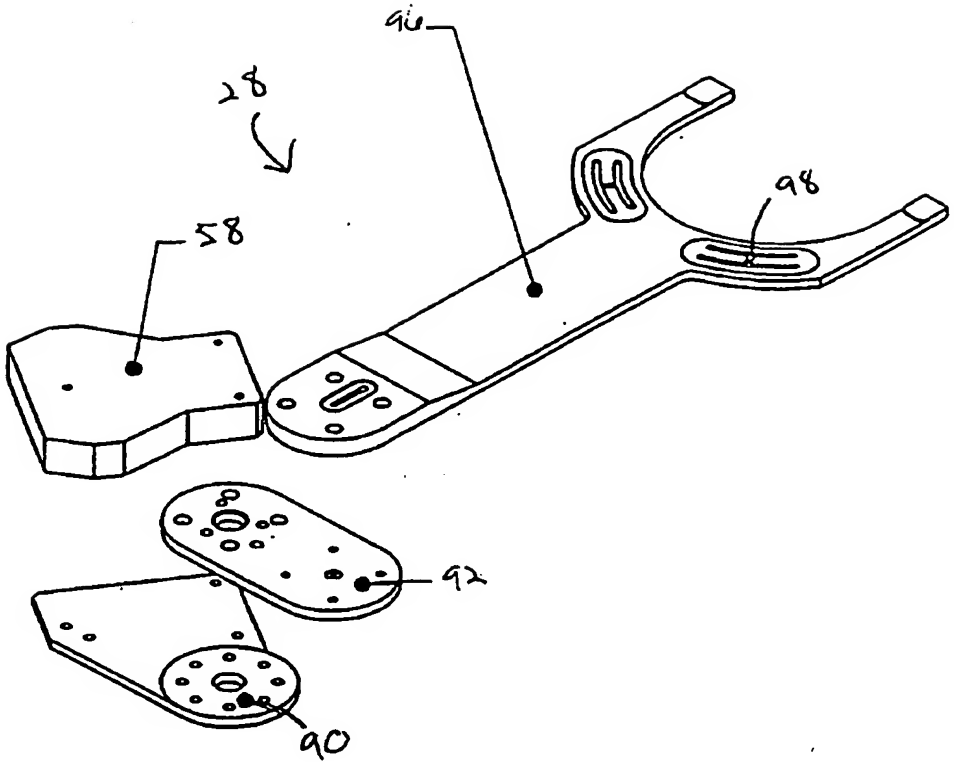

Fig. 5

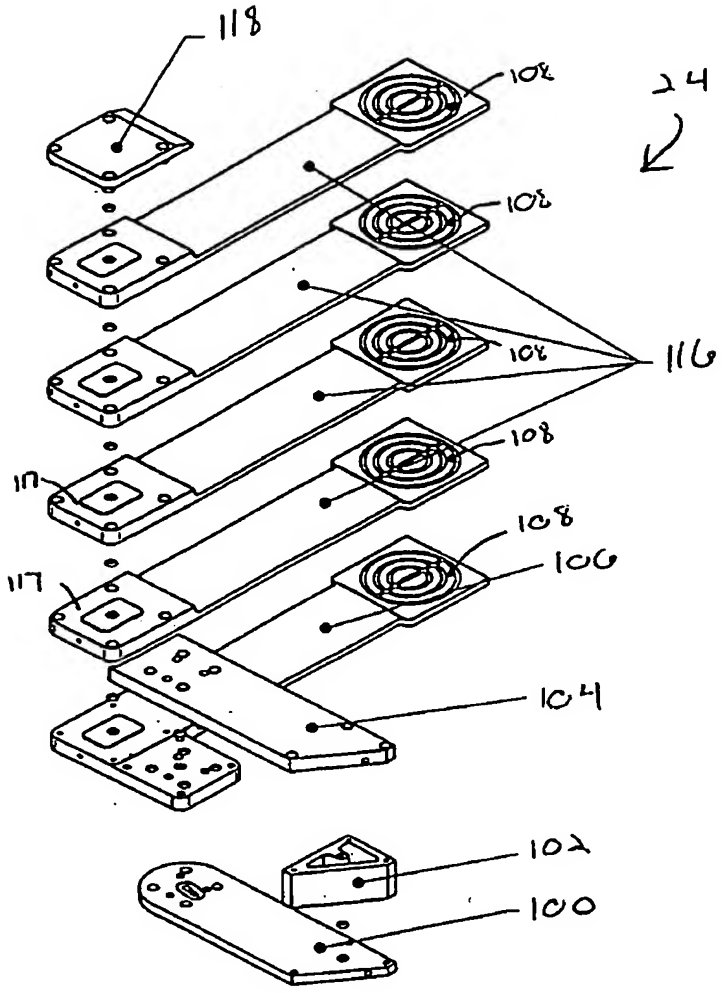

Fig. 6

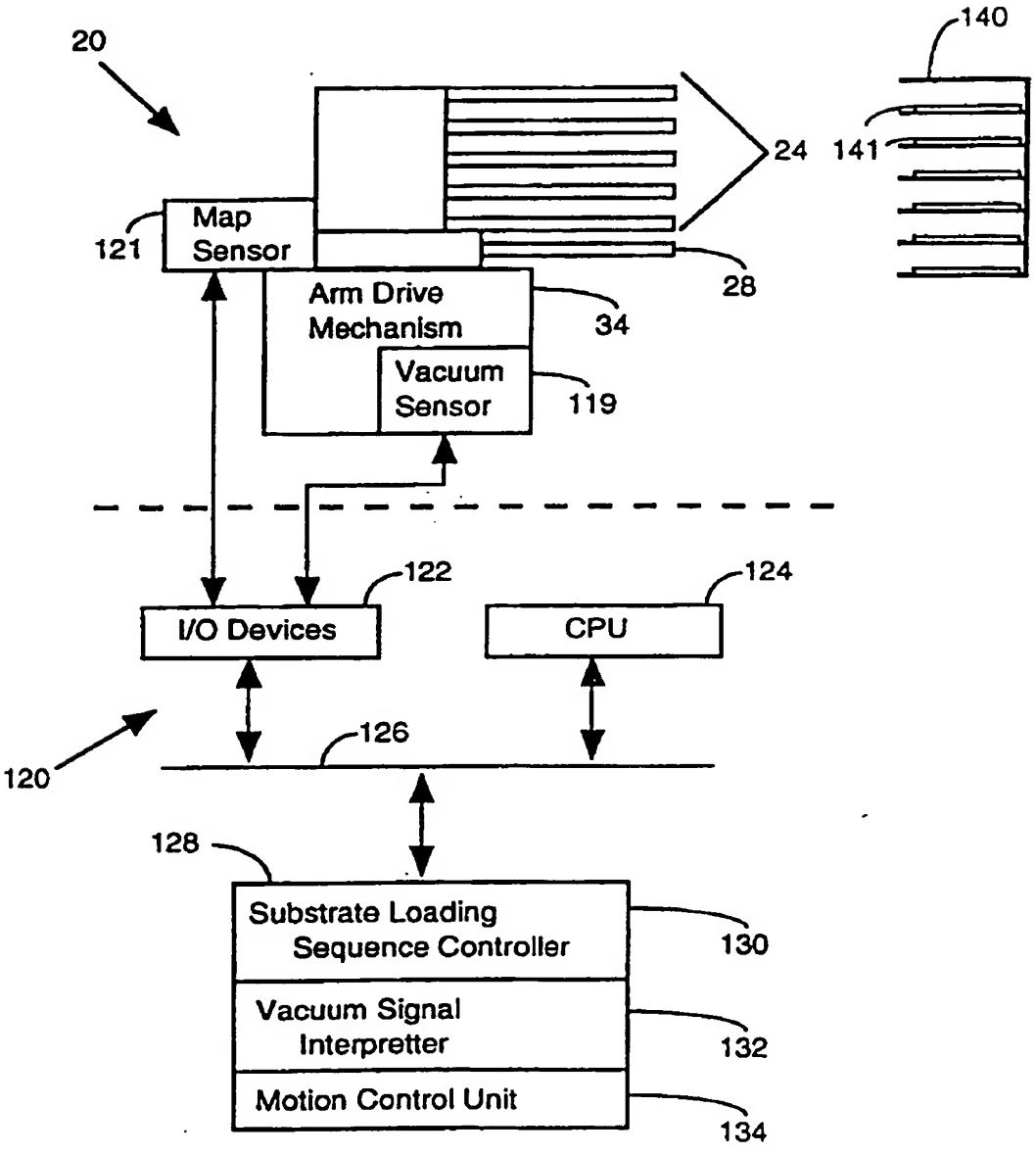
20
140
24
141
121
Map Sensor
28
Arm Drive Mechanism
34
Vacuum Sensor
119
122
I/O Devices
124
CPU
120
126
128
Substrate Loading Sequence Controller
130
Vacuum Signal Interpretter
132
Motion Control Unit
134

Figure 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/15484

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) : B65G 49/05
US CL : 414/744.5, 815
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 414/217, 222.07, 222.13, 225.01, 226.01, 416, 744.3, 744.5, 744.7, 815, 937; 294/2, 86.4, 902

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	JP 4,061,146 A (YASUTAKE) 27 February 1992, Figures 1-5 and Abstract.	1-2, 10 ------ 3-9, 11-14
X --- Y	US 5,655,871 A (ISHII et al.) 12 August 1997, col. 3, line 43 to col. 6, line 67.	1-2, 7-10, 13-14 ------- 3-6, 11-12
Y	US 5,183,370 A (CRUZ) 02 February 1993, col. 2, line 39 to col. 6, line 29.	3-6, 11
Y	WO 9,205,920 A (BOREN et al.) 16 April 1992, Figure 5 and Abstract.	7-9, 12-14
A	US 5,584,647 A (UEHARA et al.) 17 December 1996.	1, 10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 25 SEPTEMBER 1999	Date of mailing of the international search report 22 OCT 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer JAMES W. KEENAN Diane Smith Jr Telephone No. (703) 308-1113

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/15484

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Internal application No.
PCT/US99/15484

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I, claims 1-9, drawn to a robot.
Group II, claims 10-14, drawn to a method.

The inventions listed as Groups I and II do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: Group I requires a robot having two arms with a multiple substrate batch loader on one arm and a single plane end effector on the other arm. Group II involves removing substrates from a storage site using both a single paddle and a multiple substrate batch loader having multiple paddles. However, utilizing these paddles in the method of Group II does not require using the robot with first and second arms as set forth in Group I. Furthermore, the robot of Group I does not have to be used in a method of removing substrates from a storage site.